Phase 2 Project Summary

Firm: CFD Research Corporation
Contract Number: NNX11CC08C
Project Title: A Miniaturized Sensor for Microbial Monitoring of Spacecraft Water Environment

Identification and Significance of Innovation:
NASA has identified real-time, in-orbit monitoring and evaluation of microbial content in water to be of paramount importance to astronauts' health, proper functioning and control of Life Support Systems, and ultimately mission success. Conventional assays largely rely on time- and labor-intensive sample preparation and measurements, a process that is ill-suited for implementation in space. There is currently no device for rapid, automated, and label-free microbial sensing and monitoring in spacecraft water environment.

Technical Objectives and Work Plan:
In response to this challenge, the objective of this project was to develop (design, fabricate, test and demonstrate) a novel miniaturized, automated, label-free sensor for microbial monitoring in spacecraft water environment. Our approach aims to accomplish the project goals through an innovative combination of macrofluidic continuous-mode preconcentration, microfluidic focusing, and impedance-based sensor. Specific Phase 2 objectives were (from Phase 2 proposal):

- Optimally design the major sensor components, viz., macrofluidic preconcentrator, microfluidic focuser, and impedance-based detector.
- Refinement of fabrication procedure, and material and experimental protocols
- Extensive characterization and validation of components using 'Fab5' bacteria and other microbes of NASA interest
- System design and integration of critical components into a single miniaturized cartridge along with COTS components and peripherals for automated operations
- Prototype demonstration for microbial detection using composite microbial samples at multiple concentration levels
- Technology transfer and commercialization efforts (during Year 2 and beyond)

Technical Accomplishments:
During Phase II project execution, we have developed two – Dielectrophoresis (DEP)-based and Bipolar Electrode (BPE)-based – filter-free macrofluidic preconcentrators with minimal biofouling to concentrate bacteria in water sample of large volumes. Experimental testing demonstrated that both preconcentrator devices can enrich bacteria by orders-of-magnitude. Protocol and design optimization/refinement were also performed to further improve the preconcentrator performance. Extensive experimental characterization was carried out to demonstrate consistent and reliable performance of our preconcentrator using mixed bacterial samples over a long period. We also developed a microfluidic focusing and impedance based sensor to count and detect waterborne bacteria. Both macrofluidic preconcentrator and microfluidic impedance sensor were integrated into miniaturized cartridges using COTS parts for automated operation. The integrated system parts result in salient performance with negligible user intervention.

NASA Application(s):
The end product of the proposed SBIR effort will be a first-of-its-kind, compact, label-free, fully automated and integrated microbial sensor device for continuous water monitoring. The device will provide NASA a powerful tool for real-time microbial detection and identification, and greatly aid in NASA's efforts to minimize microbial exposure/infection hazard, develop countermeasures, and ensure proper functioning and quality-control of Life Support Systems in spacecrafts and space stations. The device will be of direct use to NASA's ground-based research facilities and amenable for space deployment as well.

Non-NASA Commercial Application(s):
The proposed sensor technology will have direct commercial value in both federal and civilian sectors. The device can be used for shipboard wastewater monitoring or on-field assessment of water quality during military mission. The anticipated civilian applications include:

- Pre-clinical and clinical diagnostics (e.g., microbial detection in body fluids)
- Public and natural water monitoring (e.g., hospital & health site, recreational and drinking waters)
- Industrial wastewater surveillance (e.g., water treatment and food-processing plants)

Name and Address of Principal Investigator:
Yi Wang, Ph.D., CFD Research Corporation, 701 McMillian Way NW, Suite D, Huntsville, AL 35806

Name and Address of Offeror: (Firm, Street, City, State, Zip)
CFD Research Corporation, 701 McMillian Way NW, Suite D, Huntsville, AL 35806